（ 続紙 1 ）

京都大学	博士（ 農 学 ）	氏名	Choi BaekYong
論文題目	A study of foraging behavior and physiological adaptation of western drywood termite: a framework for development of novel bandage system （アメリカカンザイシロアリの摂食行動および生理適応に関する研究：新規バンデージ処理システムの開発に向けて）		

（論文内容の要旨）

The western drywood termite, *Incisitermes minor* (Hagen), is one of invaded insect species, and was first reportecd in Japan in 1976. Since that date, 24 out of 47 prefecture have been infested by *I. minor*. At present, there is no reliable market information on termite control and repaired of damage by *I. minor* in Japan because of relatively short propagation period that caused the little economic impact.

With current pest management industry standard for detection/inspection and remedial treatment, it is hard to prevent drywood termite infestations for some reason including; 1) the lack of knowledge of foraging behavior and biological adaptations of drywood termites that involve survival in environmental stresses and 2) the high proportion of remedial intervention which only intends to kill drywood termites present at the time of application, whereas no preventive treatment which intends to stop or prevent reinfestation. Consequently, the drywood termite management should understand the foraging behavior and biological adaptations of drywood termites to provide a framework for improving efforts at detection and control when treatment is necessary. By extension, improvement and developments in the uses of remedial and preventive treatment which all aimed at minimizing detrimental side effects to structure and the environment.

The two-in-one bandage system is the result of a nearly four-year investigations on an understanding of the foraging behavior and biological adaptations of drywood termites, as well as design and implementation effort, focusing on the developing an efficient and useful application system to improve control of drywood termites in local infestation and provide a competitive cost advantage to pest management companies and property owners.

With the development of verifiable detection technology, numbers of studies revealed the foraging and nesting behavior of drywood termites that help to understand the feeding ecology. According to the CT scanning results obtained in Chapter 2, drywood termite foragers have distinguished foraging patterns based on the physical properties of wood during gallery construction, and foragers primarily excavate along the springwood towards the outer surface of the wood to

establish the primary and satellite chambers, followed by mainly superficial longitudinal expansion, and occasional lateral direction expansion. These unique foraging behavior of drywood termites aids the development and optimization of the application of remedial treatment using solid carbon dioxide as a chilling agent.

Results in Chapters 3 and 4 add on to a literature developed in the 1990s and 2000s dealing with the response of biological adaptations of termites to the environmental stress. The mode of action in killing termite using lethal low temperature involves the formation of ice crystals in the hemolymph that destroys cellular membranes give rise to the death. Therefore, termites regulate the body temperature by the temperature of the environment evolving a diversity of competitive biological adaptation to ensure the survival under environmental stresses in nature. In Chapter 3, we examined biological adaptations in physiological elements such as water relations, carbohydrate metabolites, and cuticular structure to determine how *I. minor* withstands low temperature stress and the results show that cold tolerance of *I. minor* was influenced by some physiological elements that included low body water content and hardened structure of the cuticle. Although trehalose is a cryoprotectant in one-piece-type termite species, the result of this study indicated that trehalose did not function as a natural cryoprotectant in *I. minor*. Consequently, the author was anxious about the key factors of physiological elements of termites against environment stresses, and the studies have been conducted in Chapter 4a and 4b. As a general rule, insects live in the arid/xeric environment have evolved to tolerance than those living in mesic/hydric environments. As demonstrated in numerous comparative studies of adaptations, the results from Chapter 4a show that biological adaptations influenced the cuticular resistance in desiccating conditions. From the analysis of the chemical taxonomy of cuticular hydrocarbons, which are often exposed to a desiccating environment in termites, *I. minor* possessed greater quantities of saturated (long-chain) cuticular hydrocarbons which indicate the effectiveness of the cuticular lipids in preventing desiccation. Another objective of Chapter 4a was to investigate the immediate effects of an atmosphere with experimentally induced high levels of carbon dioxide by sublimation of solid carbon dioxide on the dehydration of termites. In an artificially induced high CO_2 atmosphere, the loss of body water from drywood termites increased, which led to increased rates of mortality. The results of Chapter 4b showed that carbohydrate metabolites, balancing of total body water and total lipids accumulate in *R. speratus* with a substantial decrease in temperature, with the effect being a slight enhancement in the cold tolerance of the species in all three contrasting locations. Within three contrasting locations, *R. speratus* populations in Kyoto had higher levels of carbohydrate metabolites

alteration, lower supercooling points, and lower lethal temperatures. The results of this study support the null hypothesis that trehalose did not function as a key role in the order of Isoptera as a physiological adaptation that ensures the survival under sub-optimal temperature.

The results in Chapter 5 indicate that the thermal conductive properties are mainly dependent on the pattern of the growth ring itself at low temperatures. In a comparison of two different $CO_{2(s)}$ forms, it appears that $CO_{2(s)}$ snow increases the thermal conductive properties of the wood species tested. This phenomenon might be caused by the faster sublimation of $CO_{2(s)}$ snow which extracts the heat energy from the immediate surroundings resulting in extreme cooling compared with $CO_{2(s)}$ slabs. Chapter 6 presents the development of a two-in-one drywood termite control application that evolves into a remedial treatment using $CO_{2(s)}$ snow and preventive treatment, imidacloprid. Similar to the result from Chapter 5, the effectiveness of the remedial treatment in a two-in-one bandage system was highly influenced by the microstructure of the wood and the dosage of the chilling agent. However, using polyurethane bandage system requires a much less chilling agent (1,200g $CO_{2(s)}$ snow) to generate the core temperature of timber achieved a lower than required critical thermal minimum in the first 3 h in the much larger volume of structural timber (0.0115 m^{-3}). As a preventive treatment, the insecticidal activity evaluations performed in this study demonstrated that imidacloprid was effective in all three concentrations. The difference in the mortality data in this study indicates that there was a significant interaction between the dosage and the exposure time.

This dissertation has presented a two-in-one bandage system, which combines of two or more treatment approaches with different mechanisms can cooperatively prohibit drywood termite eradication and prevention. Although this study shows promise for improved methods of control and prevention for drywood termites, there is potentially adjusting this new control technique/device to meet the needs of the pest management industry.

注)論文内容の要旨と論文審査の結果の要旨は１頁を３８字×３６行で作成し、合わせて、３，０００字を標準とすること。
論文内容の要旨を英語で記入する場合は、４００～１，１００words で作成し
審査結果の要旨は日本語５００～２，０００字程度で作成すること。

（続紙 ２ ）

（論文審査の結果の要旨）

木質資源の長期的有効利用は人類の生存に不可欠な要素であり、シロアリ等によるその生物劣化の防止は建築物の耐震性の確保という点からも非常に重要な課題である。米国西海岸を原産とするアメリカカンザイシロアリは、1976 年に初めてその被害が報告されて以来、現在では我が国の半数以上の都府県でその被害が報告されている。本種は木材中に深く穿孔して生息することから通常の液剤処理による防除は容易ではなく、簡便かつ効果的な新しい処理法の確立が切に求められていた。本論文は、アメリカカンザイシロアリの効率的防除法の開発を目指し、その低温耐性機構に関して調査するとともに、ドライアイスを用いた殺虫有効成分との併用による低温バンデージ処理の可能性を探ったものであり、評価すべき点として以下の３点を挙げることができる。

１．日本において経済的に重要な３種類のシロアリの低温致死温度と関連する種々の生理学的特徴を比較することによって、アメリカカンザシロアリにおける体水分率の少なさ、表皮の低水分透過度および体表炭化水素中の長鎖飽和脂肪酸の割合の高さがその低温耐性の高さと関連していることを初めて示した。

２．一般に昆虫の低温耐性にとって重要な役割を有すると考えられているトレハロースが、アメリカカンザイシロアリ及び比較として用いたヤマトシロアリにおいては低温耐性物質として重要な機能を有していないことを実験的に初めて明らかにし、シロアリにおいては行動学的適応がより重要である可能性を提案した。

３．一定量以上のパウダー状ドライアイスを用いたバンデージ処理により、実大サイズの木材中心部をアメリカカンザイシロアリの低温致死温度以下に保持しうることを証明するとともに、ドライアイス蒸気と共に殺虫有効成分を木材内部へ浸透させることが可能であることを見出し、駆除と予防の同時処理（two-in-one 処理）が可能であることを明確に示した。

以上のように、本論文は外来木材害虫アメリカカンザイシロアリの低温耐性に関する新たな知見を得るとともに、ドライアイスを用いた新規バンデージ処理システムの確立に向けた詳細な検討を行ったものであり、昆虫生理学、木材物理学、木材劣化生物学および木材保存学の発展に寄与するところが大きい。

よって、本論文は博士（農学）の学位論文として価値あるものと認める。

なお、平成２９年２月１４日、論文並びにそれに関連した分野にわたり試問した結果、博士（農学）の学位を授与される学力が十分あるものと認めた。

注）論文内容の要旨、審査の結果の要旨及び学位論文は、本学学術情報リポジトリに掲載し、公表とする。

ただし、特許申請、雑誌掲載等の関係により、要旨を学位授与後即日公表することに支障がある場合は、以下に公表可能とする日付を記入すること。

要旨公開可能日：　　年　　月　　日以降（学位授与日から３ヶ月以内）